Gaia ESA

Similarly to her predecessor – HIPPARCOS – Gaia measures distances to, radial velocities and proper motions of numerous objects (stars, asteroids, quasars etc.). Fundamental properties of the targets (such as temperature, spectral type and absolute luminosity) are estimated from spectroscopic and photometric results. The ground-based follow-up survey – Gaia ESO – deepens the achieved knowledge by providing detailed wide band spectra. It is estimated that in 2020 a complete catalogue of all observed objects will be published.

What makes Gaia different from HIPPARCOS and from any other campaign is its unprecedented scale and precision. It is estimated that Gaia will catalogue 1 billion stars, down to the magnitude of 20. The measurement accuracy is 24 microarcseconds, what can be compared to measuring the diameter of a human hair at a distance of 1000 km.

The main scientific goal of the mission can be summarized as "To determine the position and velocity of a billion stars, creating the largest, dynamic and most precise 3D map of the Milky Way". However the list of expected accompanying discovery is equally impressive: Hundreds of thousands of asteroids and comets within our Solar System; thousands of planets beyond our Solar System; tens of thousands of 'failed' stars, called brown dwarfs; twenty thousand exploding stars, called supernovae; hundreds of thousands of distant active galaxies, called quasars.

For the first time in its history, the European space Agency handed the responsibility of the complete data processing to astronomers. In order to tackle this challenge a "Data Processing and Analysis Consortium" had been created. More than 300 researchers from 18 European countries have joined their forces in order to prepare data acquisition and analysis techniques and tools. Also the scientific staff of the Royal Observatory of Belgium takes part in this consortium. Many aspects of the campaign are designed and "constructed" in ROB. The scientific rewards of the mission are in line with the local research interests and will surely lead to numerous advances in understanding evolution of stars and the Solar System.

The expertise at ROB:

Since its origin in 1826, generations of scientists in the Royal Observatory of Belgium have developed a significant expertise in the domain of the *Stellar Astrophysics* and the *Small Solar System Bodies*. One finds the reflection of this knowledge in the description of today's Research Projects. The activities of ROB scientists cover nearly whole range of the interest of the contemporary Astrophysics and consequently their competences are relevant in the context of many of Gaia's challenges. Staff members of the research group "Astronomy and Astrophysics" are participants of Gaia's data processing Coordination Units (CUs). Table 1 summarizes the participation of the ROB in various CUs.

CU1 – System Architecture	
CU2 – Data Simulations	
CU3 – Core Processing	
CU4 – Object processing	
Dr Therry Pauwels	Software for astrometric reduction of Solar System objects.
CU5 – Photometric Processing	
CU6 – Spectroscopic Processing	
Dr Ronny Blomme **Dr Yves Fremat**	Software for data reduction from Radial Velocity Spectrometer. Software for deriving radial velocities based on different methods: By Cross Correlation in Fourier Space and minimum distance method.
CU7 – Variability Processing	
Dr Jan Cuypers	Software analyzing all aspects of the variability of the Gaia data, with most emphasis on stellar objects and search for periodicity.
CU8 – Astrophysical Parameters	
Dr Yves Fremat **Dr Alex Lobel** **Dr Ronny Blomme**	Software for estimating astrophysical parameters such as temperature, surface gravity, rotation rate and extinction. Software for detection and categorization of the so called “extreme stars” (e.g WR Stars and Be Stars).
CU9 – The catalogue	

CU4 at ROB:

The *Small Solar System Bodies* such as *comets* and *asteroids* are also detected by Gaia's instruments. These objects need to be automatically filtered from the field of stars and handled further with dedicated software. Estimation of the position of an asteroid in the plane of the sky, as well as its transversal velocity may be more complicated than for stars. Because asteroids are relatively close to Gaia, unlike stars, they will substantially change their positions between subsequent scans of the same region of the sky which is not optimal for astrometry. The scientific gain of Gaia in the domain of Small Solar System Object is important since placing Gaia in the Lagrange Point 2 means that she sees regions which are not possible to observe from the Earth. First observations of asteroids in ROB took place already in XIX century. At present project RUSTICCA is dedicated to search for unknown asteroids and monitoring the known ones. Scientists of ROB were responsible for software-packages that identify asteroids in Gaia's field of view and perform astrometry.

CU6 at ROB:

It has been already mentioned that thanks to Gaia data, not only the current positions of the detected stars are determined but also their movements through the 3D space. Knowing their present direction we can track stars back and see where they have been before. In this manner astronomers gain unprecedented picture of the Milky Way Galaxy's evolution. Knowledge about the former positions and surroundings of a particular star adds also a whole new dimension to the Astrophysical research after Gaia. Measurement of the star's velocity along our line of sight is done based on the Doppler's effect. The determination of the movement in the plane of the sky calls for a different technique.

Many scientists at ROB focus daily on the binary stars – in such systems two stars rotate around their common mass-center and knowledge of this movement helps to determine precise mass of both bodies. The determination of velocities in a double system calls for exactly the same technique as determination of velocities along the line of sight for Gaia's objects. Furthermore, members of ROB have helped to install the HERMES spectrograph on the MERCATOR telescope. Because the reduction pipeline for this instrument was implemented in ROB it is not surprising that members of the Belgian institute were asked to take part in development of algorithms which automatically estimate radial velocities from Gaia's spectroscopic data.

CU7 at ROB:

Because Gaia watches each of its objects on average 80 times, a set of 80 short light-curves and spectra for each star gets acquired over 5 years. This gives possibility to compare the brightness and spectral features of these objects across time, in search for the variability. Variability is an important stellar feature as it is believed that all stars are *intrinsically variable*. Furthermore strong intrinsic variability seems to characterize object at particular evolutionary stages and it can also be used as a "tool" to estimate particular features of stars in question – such as chemical composition and structure. There exists also a range of phenomena gathered under a common name of *extrinsic variability,* such as variability due to eclipses in a double system. Both kinds of variability (which split in turn in numerous sub-categories) are investigated in ROB, (see Asteroseismology and Binarity). Due to their expertise with techniques such as period analysis and modeling, members of ROB were invited investigate variability in Gaia data. They coordinated development of the tools that automatically search for variability and periodicity in Gaia data and, where possible, further categorize the new found variable objects.

CU8 at ROB:

As already described – the characterization and classification of millions of new stars is one of the profound gains from the Gaia mission. The challenge hiding behind this goal can be summarized as follows: Astronomers have defined numerous groups of stars. For example: There are very hot stars, and cooler stars, there are evolved stars and newly borne objects. Some stars are embedded in binary systems and some stand-alone etc. This classification is chiefly based on the analysis of the stellar spectra. It is vital that also objects detected by Gaia will be automatically and correctly grouped in such categories. This is the reason why experts in spectral characteristics of particular groups of stars are most qualified to incorporate all known nuances of particular spectral categories in effective computer codes. At ROB particular focus has always laid on the hot and massive stars, stars undergoing severe mass-loss as well as on evolved and variable stars. Participants of the CU8 gathered spectra of known hot and massive stars and, thanks to the computer simulations, produced synthetic spectra. In this way they have prepared a grid of reference. The spectra soon arriving from Gaia will be automatically compared to the reference objects and consequently newly discovered objects will be correctly characterized and categorized.

Gaia ESO Survey at ROB:

In order to maximally utilize results of the Gaia space mission, a ground based follow-up survey has been accepted. Because Gaia carries a short-band spectrograph, some classes of objects (e.g. Hot stars) may not display its most interesting spectral features in this narrow window. The Gaia ESO Survey makes use of VLT FLAMES instrument on UT2 telescope in order to obtain more than 10^5 wide-band spectra for the study of the formation and evolution of the Milky Way and its stellar populations.

Since hot and massive stars form an important field of research at ROB, members of the institute cooperated on this project. Elements of the observation strategy and object selection were implemented at ROB as well as packages which automatically estimate stellar properties based on spectra for O, B and A stars.